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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабаршысы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Web of Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабаршысының Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді мультидисциплинарлы контентке адалдығымызды білдіреді.

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DEVELOPMENT OF AUTONOMOUS PHOTOVOLTAIC SYSTEMS WITH SMALL POWER

Abstract. The development of autonomous photovoltaic systems is one of the most pressing problems in the electric power industry. One way to get cheap and affordable energy is solar energy. The structure of an autonomous photovoltaic cell, its main functional blocks, is considered in the article. The basic physical quantities concerning batteries and their connection are also considered. To construct autonomous low-power photovoltaic stations (up to 3000 W), accurate calculations are needed to identify the necessary and sufficient capacity of storage batteries, as well as the necessary power of solar cells. For this purpose, energy costs have been modeled, and calculations of the load during the day have been made in an apartment building with an average set of electrical appliances. The number of battery packs necessary for correct operation of the system was calculated. Based on the received data, calculations were made and a graph of the battery discharge at nighttime in the winter period was constructed.

Key words: solar cell, inverter, controller, capacity of accumulator, load power.

Introduction. In the world practice, two forms of power supply for objects are widely used: centralized and autonomous [1-3]. In recent years, the desire to introduce clean technologies contributes to the most active development of autonomous power supply using renewable energy sources. The use of solar energy in Kazakhstan is one of the most promising key topics of development of alternative energy.

Autonomous systems today have become an integral part of various SMART systems. To operate correctly any autonomous system requires a power source, as well as a way to communicate with the environment and a device for exchanging information with the dispatcher [4-6].

Very often there is a need to deploy a system that will be able to operate without external power supply, that is, perform certain operations in the field in the absence of a power source, being an independent source of energy for various needs of the consumer. Such autonomous systems can completely replace fuel electric generators.

As a power source for low-power and flexible autonomous systems are photoelectric converters or solar cells [7-10]. The constant increase in the cost of fossil energy resources and the associated incidental environmental problems increase the interest in alternative, renewable energy sources, of which solar power and solar photo batteries in particular occupy an important place. The efficiency of solar batteries is determined by their efficiency (Efficiency), maintenance costs and the cost of batteries. Data on the cost can be found from a specific manufacturer, and in many respects this factor is determined by the technology of manufacturing the battery.

Another important problem is the accumulation of energy generated by solar panels. To date, there are a lot of different batteries with different parameters, the choice of which depends on what we will be feeding, what load to use, and for how long this load will function.

Structure of the autonomous photovoltaic system. When you design photovoltaic systems, the first step is to determine the level of load power, the number of consumers and the schedule of their operation. Then, depending on what kind of load is required, a selection of solar cells and batteries is made. Depending on the capacity and the nominal voltage, the battery charge controller is selected.

The market of solar batteries is constantly replenished with new models with different capacities. When you choose solar cells, remember that the output power of the solar array should be at least 1.5 times higher than the power of the connected load to provide power in the winter months or in cloudy weather. When you calculate the capacity of the battery pack, remember that manufacturers recommend not to discharge batteries below 70% of its capacity to extend the service life. The required capacity of the battery pack is calculated by the formula (1):

$$C_N = \frac{100}{S_r}\frac{P_L}{U_N}\Delta t_{nt} \quad (1)$$

where S_r is the degree of battery rarefaction, P_L is the maximum load power, U_N is the nominal voltage of the battery, and Δt_{nt} is the duration of the night time. Then in order to find the number of batteries necessary to power the system, you should divide the received capacity by the nominal capacity of the battery, expressed in Ah (ampere hours).

$$N = \frac{C_N}{C} \quad (2)$$

Where C_N is the required capacity of the battery pack, C is the capacity of one battery.

When you choosing the inverter, the most important parameter is the power it is designed for. For low-power autonomous systems with a power of up to 1500 W, high-frequency inverters are sufficient, which have a relatively low weight. For higher powers, low-frequency inverters should be selected. Some inverters have a built-in battery charge controller. The most common battery charge controllers are the controllers that monitor the maximum power point (MPPT – maximum power point tracker). Such controllers constantly monitor the current and voltage on the solar battery and find the optimal current-voltage pair at which the power is maximal. In the same way, the controller keeps track of which battery stage the battery is in and provides the corresponding current.

Results and discussions. To develop a photovoltaic system with a power of 1.5 kW, six solar panels with a power of 250 W each are required. The maximum voltage is 32.5 V, the current is 7.9 A (table 1).

Table 1 – Calculation of voltage and current in different commutation of solar panels

U	32,5	65	97,5	195
I	47,4	23,7	15,8	7,9
P	1540,5			

When we choose a battery, we use formula (1) and calculate the capacity of the battery pack. To do this, we need to simulate the consumption of one residential house within a day. The results are summarized in table 2. With this load, using equation (1), we can calculate the capacity of the required battery pack. So, we need 6 (equation 4) batteries with a capacity of 200 Ah (3-4).

Table 2 – Total energy consumption during one day

Consumer	Power, W	Time of work, h	Energy consumption, Wh/day
Electric kettle	1000	0.25	312.5
Microwave	1200	0.25	375
Fridge	250	24	7500
TV	150	4	750
Lighting 1	100	4	500
Lighting 2	50	2.083	130.2083
Computer	400	0.83	416.67
Modem	6	24	180
Washing machine	150	1	187.5
Total			**10991.875**

$$C_N = \frac{100}{S_r}\frac{P_L}{U_L}\Delta t_{nt} = 1204{,}76\ Ah \quad (3)$$

where S_r = 70%, P_L = 632,5 W, U_L=12 B – nominal voltage of the battery, Δt_{nt} = 16 h.

$$N = \frac{1204{,}76}{200} \approx 6 \quad (4)$$

Table 3 – Load change diagram during a day

	Electric kettle, W	Micro-wave, W	Fridge, W	TV, W	Lighting 1, W	Lighting 2, W	Computer, W	Modem, W	Washing machine, W	Load power , W	Rated load power , Wh
7:00-7:05	1250		312,5			62,5		7,5		1632,5	136,04
7:05-7:10		1500	312,5			62,5		7,5		1882,5	156,875
7:10-8:00			312,5			62,5		7,5		382,5	318,75
8:00-13:00			312,5					7,5		320	1600
13:00-13:05	1250		312,5					7,5		1570	130,83
13:05-13:10		1500	312,5			62,5		7,5		1882,5	156,875
13:10-14:00			312,5				500	7,5		820	683,33
14:00-16:00			312,5					7,5		320	640
16:00-17:00			312,5					7,5		320	960
17:00-18:00			312,5					7,5	187,5	507,5	507,5
18:00-18:05	1250		312,5			62,5		7,5		1632,5	136,042
18:05-18:10		1500	312,5			62,5		7,5		1882,5	156,875
18:10-19:00			312,5			62,5		7,5		382,5	318,75
19:00-23:00			312,5	187,5	125			7,5		632,5	2530
23:00-7:00			312,5					7,5		320	2560
Total power kWh/day+night											**10991,87**
Total power kWh/night											**7780,83**

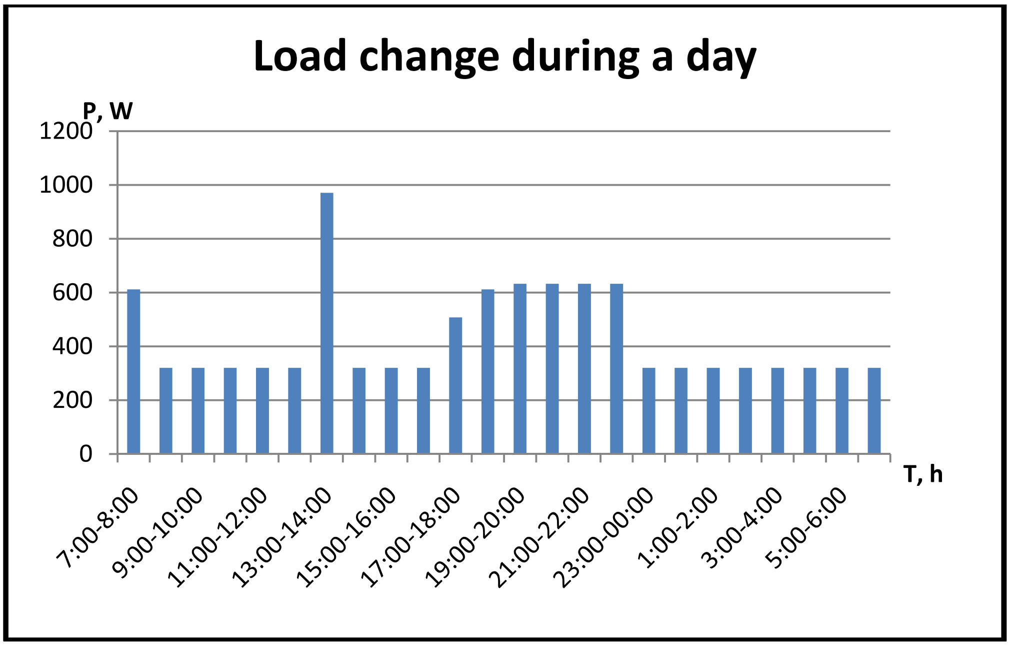

Figure 1 – Load change during a day

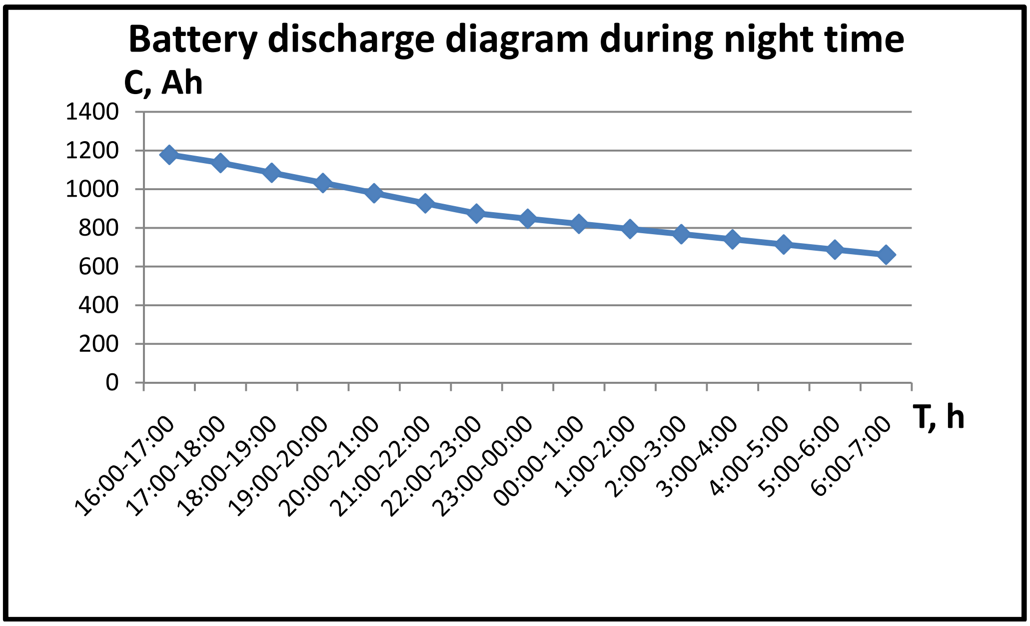

Figure 2 – Battery discharge diagram during night time

According to the schedule of load changes (table 3) per day we will construct a schedule for changing the capacity of the battery pack (figure 1, 2). The discharge of batteries starts at 16:00, which corresponds to the sunset in the winter season. With this battery operation pattern, the service life will be extended, since the design depth of the discharge is at least 54%.

Conclusion. The development of autonomous systems plays a huge role in the transition of energy to renewable sources, enables consumers to use cheap and affordable electric energy and not depend on the central power supply. Moreover, autonomous solar power stations of low power will become indispensable sources of energy for individual farms, for the development of agriculture for the supply of agricultural equipment. The results presented in the article can be used to design an autonomous solar power station with a capacity of 1.5 kW that can supply a small house with electricity.

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АЗ ҚУАТТЫ АВТОНОМДЫ ФОТОЭЛЕКТРЛІК ЖҮЙЕНІ ДАЙЫНДАУ

Аннотация. Автономды фотоэлектрлік жүйені дайындау электроэнергетикадағы аса өзекті мәселелердің бірі болып табылады. Арзан және қолжетімді энергия көзін алу әдістерінің бірі күн энергетикасы болып табылады. Мақалада автономды фотоэлектрліктің құрылысы, оның негізгі функционалды блоктары қарастырылған. Сонымен қатар аккумуляторлық батареяларға және олардың байланысына қатысты негізгі физикалық шамалар қарастырылған. Аз қуатты (3000 Вт-қа дейін) автономды фотоэлектрлік станцияны құрастыру үшін аккумуляторлық батареялардың қажетті және жеткілікті сыйымдылығын, сонымен қатар күн батареясының қажетті қуатын анықтауға қажет нақты есептеулерді жүргізу қажет. Бұл үшін энергия шығыны үлгіленген және электр құралдарының орташа жинағы бар тұрғын үйде бір тәулік аралығында өндірілетін жүктеменің есептеулері жүргізілген. Жүйенің дұрыс жұмыс істеуіне қажет аккумуляторлық блоктардың саны есептелінген. Алынған мәліметтерге негізделе отырып, қыс мезгіліндегі түнгі уақыттағы аккумулятор зарядының бітуінің графигі құрылған және есептеулер жүргізілген.

Түйін сөздер: күн батареясы, инвертор, контроллер, аккумуляторлық батареялардың сыйымдылығы, жүктеменің қуаты.

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РАЗРАБОТКА АВТОНОМНЫХ ФОТОЭЛЕКТРИЧЕСКИХ СИСТЕМ МАЛОЙ МОЩНОСТИ

Аннотация. Разработка автономных фотоэлектрических систем является одной из наиболее актуальных проблем в электроэнергетике. Одним из способов получения дешевой и доступной энергии является солнечная энергетика. В статье рассмотрена структура автономной фотоэлектрической, ее основные функциональные блоки. Так же рассмотрены основные физические величины, касающиеся аккумуляторных батарей, и их связь. Для конструирования автономных фотоэлектрических станций малой мощности (до 3000 Вт) необходимо произвести точные расчеты для выявления необходимой и достаточной емкости аккумуляторных батарей, а также необходимой мощности солнечных батарей. Для этого смоделированы энергозатраты, и произведенырасчеты нагрузки в течение суток, производимые в жилом доме со средней комплектацией электроприборов. Было вычислено количество аккумуляторных блоков, необходимых для корректной работы системы. Основываясь на полученных данных, произведены расчеты и построен график разряда аккумуляторов в ночное время суток в зимний период.

Ключевые слова: солнечная батарея, инвертор, контроллер, емкость аккумуляторной батареи, мощность нагрузки.

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